Journal by Alexander Graham Bell, from January 2, 1903, to August 26, 1904

11

1903, May 6, Wednesday At Conn Ave.

AREA OF TRIANGLES.

Area of 100 cm. triangle = 4330.000

Area of “ “ 50 cm. triangles “ = 1082.500

Area of “ “ 25 cm. triangles “ = 270.625

<u>WEIGHTS OF WINGED TETRAHEDRAL CELLS.</u>

Grammes per Square metre. 25 cm. Cell. 50 cm. 50 cm. Cell. 100 cm. Cell. 100 5.4125 21.65 86.60 200 10.8250 43.30 173.20 300 16.2375 64.95 259.80 400 21.6500 86.60 346.40 500 27.0625 108.25 433.00 600 32.4750 129.90 519.60 700 37.8875 151.55 606.20 800 43.3000 173.20 692.80 900 48.7125 194.85 779.40 1000 54.1250 216.50 866.00

Length of Framework.

25 cm. cell 150 cm.

50 cm. “ 300 cm.

100 cm. “ 600 cm.

1

1903, June 27, Saturday At. B. B. Lab.

I made my first appearance at Beinn Bhreagh Laboratory this season on Monday, June 15, 1903, my Secretary, Mr. Mitchell, arrived next day, but we have been unable to begin laboratory notes until today and we can only make a beginning today as time is short.

The present staff consists of myself with Mr. Mitchell as Secretary and Mr. George McCurdy as Photographer and Special Assistant. I employ Mr. Angus Ferguson as head workman to run the laboratory and he employs for me, assistant workmen as may be required. At present Mr. McNeil is Assistant Workman in the laboratory.

Regular hours for workmen 8:00 A. M. to 4:00 P. M., but they are to stay later when required exceptionally.

Mr. George McCurdy is to be at the laboratory every day from 2:00 until 3:30 at my disposal, either to photograph experiments, or to assist me in other ways. Any photographs taken are to be developed the same day, between 3:30 and 5:00 o'clock. Three paper prints are to be made the next day, printing and fixing to be completed before 2:00 o'clock. At 4:00 o'clock, two paper prints of each photograph to be handed to Mr. Mitchell for preservation in our laboratory records.

2

Mr. Mitchell, acting as Secretary of the laboratory is to be on hand at the laboratory at 4:00 o'clock. He will then take the paper photographs and mark upon them, the date of receipt and paste one set in the laboratory photograph album, to be kept at the laboratory annex, and keep the other set as separates in his office. Mr. Mitchell is to remain at the laboratory from 4:00 to 5:00 o'clock to make such records of laboratory work as I shall direct.

A. G. B. is to be at the laboratory from 2:00 until 5:00 P. M. Experiments to be conducted between 2:00 and 4:00 P. M. Photographing of experiments will cease at 3:30, the time between 4:00 and 5:00 P. M. to be devoted to making records by dictation or otherwise of laboratory work, thoughts etc.

These arrangements to constitute the regular program of work, but as we cannot control the wind, and we do not have many days here suitable for kite flying, experiments may be continued after 4:00 o'clock during daylight, when we have good wind favorable for trying our heavier kites.

A. G. B.

The dictated notes are to be press copied, the notes to be preserved in the laboratory annex, the press copy book to be kept in Mr. Mitchell's office.

A. G. B.

3

1903, June 29, Monday At. B. B. Lab.

The whole laboratory has been at work since I returned, on making tetrahedral frames. Mr. McNeil has been making frames of spruce, as light as possible, — lighter than our original red silk kite. The frames he has completed for four-celled kites (25 cm. cells) weigh 34 grams each.

Mr. McNeil has made a great improvement in the method of constructing these cells of very light and thin sticks. Holes are bored at the ends, and to prevent the sticks from splitting while the holes are being bored, the ends of the sticks are shoved into a “V-shaped” space formed by two pieces of wood fastened on the bench,

The string used to tie the sticks together is first threaded through the holes at the end of a stick, and then tied around the stick so as to prevent splitting, the sticks can then be tied together very firmly. Another improvement consists in cutting the ends of the sticks to an angle to make them fit together without over-lapping, this makes a strong and symmetrical joint.

Still another improvement made by Mr. McNeil in constructing a framework for a four-celled kite — which is 4 our unit for larger construction — is, to make four 25 cm. triangles and then connect them together at the corners, thus forming a frame of octahedral shape,

This octahedral frame fits nicely into the interior of a 50 cm. tetrahedral frame completing the framework for a four-celled kite,

Mr. Ferguson has been at work making tetrahedral frames of heavier construction (50 cm. cells).

AGB W.M.M

5

1903, July 15, Wednesday At. B. B. Lab.

We have been unable as yet to settle down to regular notation of laboratory work, so that the only records we have are contained in the laboratory scribbling book, and the photographic record kept by George McCurdy — now amounting to 40 pages of photographs.

Pansy Lodge has been removed to the laboratory and has been placed beside the dark room as an office for Mr. Mitchell. Although not yet completed, work was commenced in it yesterday.

We have additional assistance in the laboratory in the shape of a young lady, Miss Elsie Taylor, who is employed in sewing on silk wings.

Some of the wind-break cells have been built up into a tetrahedral form to illustrate the strength of the structure. Photographs were taken of this structure on Monday, June 22, with three men standing inside it at the weakest part, no perceptible sag was produced by their weight. (See photograph No. 21).

Photograph No. 22 shows a sixteen-celled tetrahedral kite flying from bamboo pole. The cells are 25 cm., covered with red silk, weight 186 gms, surface 0.8660 sq. meters, ratio 215 gms. per sq. meter. (See Lab. Notes, Page 38, June 30)

6

Four kites similar to the above were fastened together to form a 64-celled kite, which is shown in photograph No. 57, taken July 6. Photograph No. 58, also taken July 6, shows the 64-celled tetrahedral kite flying from bamboo fishing rod, weight 744 gms, surface 3.4640 sq. meters, ratio 215 gms. per sq. meter.

Copies of these photographs, (No. 57 and No. 58) were sent to Mr. Chanute, Prof. Willis Moore, Prof. Langley, Prof. W. J. McGee, Mr. Phillip Mauro, and Mr. A. W. McCurdy.

AGB

7

1903, July 20, Monday At. B. B. Lab.

Mr. Ferguson left this morning for a three days fishing trip with Mr. McInnis and Mr. Davidson, and owing to the inclemency of the weather Dr. Bell did not try any experiments in the field. His father, Mr. Melville Bell came down to the Secretary's office and spent part of the afternoon with Dr. Bell, reading, talking etc. On his departure Dr. Bell wished to dictate some laboratory notes but finding the Secretary's office too cool and damp, he abandoned his notes for the day and requested his Secretary to make some note of his reasons therefor.

W.M.M.

8

1903, July 21, Tuesday At. B. B. Lab.

Mr. Ferguson being away on his fishing trip, and the inclemency of the weather preventing field experiments, Dr. Bell has been givin g his attention to matters other than those pertaining to kites. As a matter of daily record, Mr. Mitchell, his Secretary, keeps up the laboratory notes when Dr. Bell cannot devote his own time thereto.

W.M.M.

9

1903, July 24, Friday At. B. B. Lab.

Today Mr. Bell flew a large four-cell kite covered with red silk, the framework being of aluminum, each cell measuring 50 cm. The kite flew remarkably well, in fact surpassing the flight of any previous four-cell kite.

A 25 cm. four-celled aluminum kite frame fastened together at the corners and centers by bronze castings, stood a remarkable test by bearing the weight of George McCurdy weighing 150 pounds, both by standing on the frame and hanging from it while suspended from a joist.

The weather for the past few days has been too inclement to permit of any field experiments, but Dr. Bell hopes to carry on some field work tomorrow.

W.M.M.

1

1903, October 30, Friday At B. B. Balloons Versus Flying Machines

By A.G. Bell

Notes Dictated by A. G. B. to M. G. B.

Oct 30, 1903: — The supporting power of a balloon increases as the cube of the diameter whereas the weight of the envelope increases only as the square. In flying machines, on the other hand, the supporting power increases only as the square whereas the weight increases as the cube, (this is on Newcomb's assumption, excepting that in the case of the Balloon the thickness of the envelope is assumed constant for balloons of different sizes.)

From these facts it follows: 1, That it would be easy to construct a large balloon that would fly and difficult to construct a small one. 2, It would be easier to construct a small flying machine that would fly, than a large one.

A machine that will carry a man in the air must necessarily be large and the above considerations afford an explanation why man lifting balloons have been developed before man lifting flying machines. I mean “developed” as an actual fact, — not theoretically on paper.

Even assuming that the thickness of the balloon envelope is increased proportionally to the increase of the diameter, then the weight of the balloon will increase as the cube of the diameter and the supporting power being dependent on the cubic capacity of the balloon; (that is — upon the amount of gas it will hold) will also increase as the cube of the diameter. So, that given a balloon that will fly, we can increase its dimensions to any desired extent in perfect confidence that the larger structure will fly as 2 well as the smaller

It is different however with flying machines. Numerous small models of flying machines have been made which have actually flown, and the inventors have naturally assumed that a large machine on the same model would be equally successful — but after they have gone to the trouble and expense of constructing machines supposed to be large enough to carry a man, the apparatus has not flown — at least the world has not heard of the successful flight of man-bearing flying machines upon the models of the small machines that would fly. From Henson up to Maxim and Langley the promising experiments have not been attended with success. I think this has been largely due to the fact that it has not been sufficiently appreciated that the supporting power derived from aeroplanes or aero-surfaces only increases in direct proportion to the surfaces themselves, that is in proportion to the square of the dimensions, from which it follows, — that large machines can only be as efficient as small ones, where the weight increases in no greater proportion that the surface. We cannot too clearly realize that the old idea is a fallacy that a large flying machine on the same model as a smaller one will necessarily fly as well.

Let us assume that as we increase the dimensions of our machine we increase proportionally the length, breadth and thickness of all its parts, — then the weight increases as the cube of the dimensions. Now let our machine take the form of a balloon filled with hydrogen gas that will rise in the air when released. The ascensional power depends on 3 the quantity of gas and the weight is the weight of the envelope and contained gas. Now build a balloon of just twice the diameter it will hold just eight times the amount of gas the envelope will weigh just eight times the envelope of the smaller one if the material composing it is twice as thick.

The weight of the whole balloon will then be eight times as much as the smaller balloon and the ascentional power also eight times. The large balloon will therefore float as well as the smaller.

But suppose we make our machine in the form of a flying machine dependent for support on aero-planes, and let it be a successful flyer. Now build another of just double dimensions, increasing proportionally the length, breadth and thickness of all the parts, then the weight will be eight-fold that of the smaller machine while the supporting surfaces would be only four-fold.

Thus increased size in a balloon does not diminish efficiency to support a load, whereas in a flying machine of any given model, the efficiency is seriously diminished by increased size.

AGB 3

4

1903, Nov. 13, Friday At. B. B. 10 First Experiments with Tetrahedral Kites

By A. G. B.

Dictation taken by M. G. B.

Nov 13, 1903:— The time is at hand when it will be necessary to close the Beinn Bhreagh Laboratory for the winter, and only a very few more days of experiment remain. It might be well then to glance the eye backward over the seasons experiments to see where we are and what problems remain to be solved before taking up the question of propulsion upon the water.

It is somewhat remarkable I think that the most successful forms of apparatus seem in nearly every case to have been developed theoretically long before their value has been demonstrated by practical experiment.

The conception of the tetrahedral cell itself , and its importance as an element in a structure , was developed in Washington the year before it was applied practically at Beinn Bhreagh, and a model , made at the time , of brass triangles , still exists in Washington. It was not until the close of the Beinn Bhreagh season of 1902 that a tetrahedral kite was actually constructed , and even then it was constructed so late in the season that very few experiments could be made before the time came for return to Washington. The results announced to the National Academy of Sciences concerning the importance of the tetrahedral principle in kite construction were really not fully justified by the experiments that had been made at Beinn Bhreagh, and I did not dare to publish them without repeating the experiments in Washington and Colonial Beach. I was so confident however in the strength of my theoretical 5 Dictation taken by M. G. B. position

— fortified by the experiments in Colonial Beach — that I published the results in the National Geographic Magazine and applied for U. S. patents.

The principal work of the present season has been the verification of the results I had announced; and the construction of a framework built up of tetrahedral cells suitable for use as a man-lifting kite capable of floating upon water.

It is also somewhat remarkable that the latest type of structure — The Victor cell-was developed and made at Beinn Bhreagh last year shortly before my return to Washington.

I was so confident at that time that the form of structure was important that I ventured to publish it in two photographs given in my paper in the National Geographical Magazine (See the Aerodrome Kite and the Kite with two boat bodies). I had already conceived the idea that the wings of the aerodrome kites would be more efficient if flown upside down, and before leaving for Washington in the autumn of 1902 I constructed such a kite with two sets of wing surfaces, arranged like the fore and aft cells of a Hargrave kite. I do not remember whether it was tried at that time, but think it was. At all events one of the wings was broken and further experiments had to be postponed. The other wing made in 1902 is still in existence, in the laboratory, and is identical in construction with the Victor kite , having two horizontal surfaces, the narrower one underneath and no oblique surfaces inside, one oblique surface being left at either side as a steadier.

6

Victor cell made in 1902

This is identical with the form of cell used in my most successful Victor kite. I have not yet settled whether the omission of the interior oblique surfaces is, or is not an advantage, but in the last comparative experiment made the kite without interior oblique surfaces flew at a higher angle and with less pull than a similar kite provided with interior oblique surfaces.

At the same time I cannot help remembering that a previous experiment gave different results.

Victor frame with interior oblique surfaces

Victor frame without interior oblique surfaces.

7

The framework was identical in both cases and also identical with the framework made in 1902. The difference between the frame of the 1902 and the 1903 kites lay not in the winged portion but in the character of the framework connecting the front and rear sets of cells. In the 1902 kite the cells were connected by longitudinal sticks with some form of cross bracing. If I recollect ly correctly the following was the arrangement.

Victor Kite of 1902

8

In the 1902 1903 kite the space between the two sets of cells is completely filled in with tetrahedral framework of the same kind as in the wings themselves—

Victor Kite of 1903

making the whole structure rigid. The light tetrahedral framework of the 1902 1903 kite is much stronger and more rigid than the much stouter longitudinal sticks of the 1902 kite, and constitutes an enormous improvement. A small kite of this kind was made for me by Mr. McNeil of as light and thin spruce sticks as possible, with 25 cm. cells. We are all surprised at the strength of the structure and we have named the kite “McNeil's Baby”. It is by no means a baby however, excepting from a comparative point of view — for the upper horizontal aeroplanes are 150 cm. long and 50 cm. wide. The lower horizontal aeroplane is 125 cm. long and 25 cm. wide and it is provided with a full set of interior oblique surfaces.

9

Victor Kite of 1903 “McNeil's baby”

The oblique surfaces are equivalent to 22-½ triangles gaving having each a side of 50 cm. McNeil's Baby turns out to be a beautiful kite flying steadily in the slightest breeze at a very high angle of cord, certainly not less than 80 degrees. Indeed when there is an absolute calm on the surface, there is generally enough wind to sustain it at an altitude of 100 M. That is : I f we attach to it a cord 100 M. long and run with the cord so as to elevate the kite in the air McNeil's Baby generally sustains itself at that elevation even though there may not be a breath of wind at the surface of the ground. It is quite the equal in this respect to of our lightest flying tetrahedral kites weighing only 250 215 grams to the square metre of surface — if indeed it is not superior. This is somewhat remarkable when we consider that the empty framework between the two wing ed pieces weighs three times as much as the frame of a wing-piece itself. Experiments were made with very surprising results to ascertain whether or not it could be possible to do away with the empty framework and altogether and thus lighten the kite still more.

10

The two wing pieces were therefore connected together directly end to end so as to make one wing piece of double the length.

A bridle was attached at the centre as shown and we tried flying it from the top of a bamboo pole. To my surprise it flew perfectly well; but a very slight change in the bridle caused it to be unsteady. We then attached to the centre a light protruding tetrahedral frame to obtain a rigid point of attachment for the string further forward than the middle point of the kite and balancing it by another tetrahedral frame at the rear.

11

1903, November 13, Friday. Dictated to M. G. B. At B. B.

When the cord was attached as shown, the kite soared and the cord appeared to be vertical or nearly so. This result is very astonishing ; x and the kite , x relieved of its load of empty framework, weighs far less per square metre of surface than any other we have yet made — or have heard of. It only weighs 147 grams per square metre of surface, so that the whole kite is lighter than the cotton cloth alone with which we formerly covered our kites — let alone the framework. The cotton cloth weighted 160 f g rams per square metre. t T he nainsook used in this kite weighs only 45 grams per square metre and the whole kite — framework and all — amounts to only 147 grams per square metre of surface. One would naturally suppose that such a kite frame would be too fragile to be of any practical use but on the contrary the frame is quite strong at the points of junction of the sticks, although the sticks individually are very thin and fragile. We have strengthened the frame by adding a beading of thicker wood all around the outer edge so as to bring the flying weight up to 200 grams per square metre, — which still makes this the lightest kite we have. It now seems to be so strong that Mr. McNeil wanted to try its strength by sitting on it, being confident he declared, that it would bear his weight. I valued the kite too highly however to permit the experiment to be made, so we do not yet know what force would be required to crush the framework in. Suffice it to say that we have succeeded in making a practically useful kite that weighs only 200 grams per square metre of surface.

AGB

12

1903, November 15, Sunday At B. B.

Nov 15, 1903:— Dictated to M. G. B.

The two wing pieces of McNeil's Baby being detachable from the body were used in the construction of the last kite described, and the body framework has been utilized in the construction of another pair of wing pieces. I have hither–to spoken of McNeil's Baby kite in the present tense as though it were still in existence, and so it is but in the same sense that the caterpiller exists in the chrysalis and the chrysalis in the butterfly. It still exists:– But as two pairs of wings without any body.

Two other kites of the Victor type made on the same general model as McNeil's Baby were — like it — made in three sections which were tied together to complete the kite.

A third kite of the same kind was made with the framework all of one piece as shown below: and — as was expected — the single frame weighed less than the similar frame made in three sections. This again emphasizes the fact that a continuous framework of tetrahedral cells weighs less proportionately if large than small. Two cubic metres of framework for example will weigh less than twice one cubic metre and when you come to large structures the average weight per cubic metre is enormously reduced. Supposing we wish to build up out of 25 cm. cells a structure as large as a house. We would naturally construct a small section of it first — say one cubic metre as a model. The weight of this cubic metre of framework we would naturally take as a sample of the whole structure and jump to the conclusion that the whole structure will weigh as many times this sample, as there are cubic metres in the structure — but this is far from being the case and the whole structure will weigh very much less per cubic metre than the sample.

This seems so extraordinary a conclusion as to demand amplification and expansion. I know it is true for 14 framework formed of tetrahedral cells, and I now see that it is also true of any kind of open framework.

It may be convenient for the purpose of demonstration to build up our framework in cubical form so that our unit surfaces may be squares and our unit volumes cubes.

A square frame of one foot has four sides each one foot long ; but it would not take four sticks each one foot long to make it — for allowance must be made for the width of the sticks.

In order to give definiteness to our conceptions let us assume that in building up a framework we use sticks of uniform cross section — say one square inch:– And further let us assume that a stick of this kind one foot long weighs one ounce.

Four sticks each one foot long would therefore weigh 4 ounces ; but a square foot of frame can be built of four sticks each only eleven inches long — because each stick is one inch wide, and thus the whole frame will weigh only 3.6 ounces.

15

Having established the fact that a frame one foot square weighs 3.6 ounces, let us consider the weight of a cubical frame of the same sort.

A cube of one foot has six faces each of one square foot, but it would not take six square frames like the above to make it, for allowance must be made for the thickness of the sticks.

Six frames each one foot square would consume 22 feet of stick weighing 22 ounces, but the cubical frame of one foot requires only 10 feet 8 inches of stick weighing only 10-# ounces (less than half the weight of six square frames.)

A cubic foot of frame can thus be made from two square frames connected together at the corners by 4 sticks each ten inches long.

Having established our unit of surface as a frame of one square foot, and our unit of volume as a cubical foot of framework, let us consider the weight of larger structures built up of such elements.

16

Surface Extension.

We would fall into error were we to assume that 2 square feet of framing need weigh twice as much as one square foot.

It is true that we could place two one-foot frames side by side.

but the doubling of adjoining sides of the two squares would evidently be an undesirable feature adding unnecessarily to the weight of the compound structure without compensating advantage. It would certainly not be advisable to use two sticks when one would do and we would therefore naturally build the compound frame as follows:

AGB

1903, March 25, Friday At Conn. Ave.

Thoughts dictated to W. M. Mitchell.

WIRELESS TELEGRAPHY

By A.G. Bell

Mar 25, 1903:— When a grounded wire is carried up vertically to a considerable height in the atmosphere, it is normally the case that the electrical potential of the elevated point is different from that of the ground, — hence a slight electrical current traverses the wire, as a normal condition.

If now the coil of a receiving telephone form part of the wire, it does not necessarily follow that any sound should be heard from the telephone. So long as the strength of the electrical current remains uniform, no sound would be perceived.

If however the ground connection be broken, a feeble click would be heard from the telephone. By making a serious of makes and breaks a serious of clicks would be perceived; and if the ground connection is made and broken with the frequency of a sound, a musical tone would be perceived from the telephone.

Let us then introduce a mechanical interrupter adapted to make and break the circuit with great rapidity so as to produce in the telephone, a musical tone of high pitch. It would be preferable to have a rotatory interrupter so that the mechanical rotation of the apparatus should not itself produce a musical tone, — the only musical effect perceived being produced by electrical means.

2

By the agency of clockwork, or by means of a little water-wheel, or by other agencies, the interrupter can be kept rotating for an indefinite time.

Now let this be done and the effect perceived at the telephone will be — a continuous feeble musical tone at of high pitch, something like the continued buzzing of a mosquito; This is the normal condition; and the whole arrangement should be exquisitively sensitive as a receiver for Herzian waves or Marconi signals.

The moment a Herzian wave reaches the receiver, the electrical potential is disturbed and the loudness of the musical notes perceived should be affected.

Upon listening at the telephone, the musical tone should be observed to swell out or become feebler and the Marconi signals would be perceived as pulsations of sound.

This plan seems to be eminently worthy of trial, because it gets rid entirely of the <u>coherer</u> — the weak point in all systems of wireless telegraphy.

It might even be possible that such an arrangement would enable spoken words to be perceived transmitted by wireless telephony, for it is well known that a telephone line carrying a telephonic message can be made and broken with great rapidity without materially interfering with the intelligibility of the speech. The electrical transmission however is effected only during the period of makes, and not at all when the circuit is broken, so that the intelligibility of the speech depends upon how much can be cut out without 3 destroying intelligibility. It would be better of course to have an unbroken circuit.

In the case of the wireless telegraph receiver described above, the interrupter would be unnecessary if speech, or signals having the frequency of a sound, were being transmitted in a wireless manner; but it is doubtful whether the telephone could distinguish slow signals spelling Morse characters, unless the circuit was interrupted or disturbed so as to produce normally a sound from the telephone and thus allow the slower signals to be perceived as variations in the intensity of the sound.

Of course it would be perfectly possible to produce an electrical disturbance in the circuit that should occasionally sound from the telephone, by induction.

For example:— Let the secondary coils of an induction coil be introduced between the elevated wire and the ground — then an intermittent, pulsatory, or undulatory current traversing the primary coils would (without breaking the connection between the elevated wire and the ground) induce in that wire a series of electrical impulses that would affect the telephone as x sound.

Some such arrangement as this might pave the way for wireless telephony.

4

The following experiments would be well worthy of trial.

Erect two poles at a moderate distance apart — far enough apart to be out of earshot from one another. Upon them attach vertical wires forming the antennae of a wireless telegraph system. In each case introduce between the antenna and the ground, the secondary coils of an induction coil. Place a telephone transmitter and battery in the primary circuit of one of the coils, and a telephone receiver (with or without a battery) in the primary circuit of the other, then I conceive it possible — nay probable — that words spoken into the telephone transmitter connected with one of the antennae should be audibly reproduced by the receiving telephone connected with the other antenna: in which case we would have the transmission of speech by wireless telephony. The only question is — how far apart might the two antennae be placed without affecting the transmission. This is a question that can only be settled by experiment. The poles should be near enough together in the first place to insure success and then greater distances could be tried.

There is no doubt whatever in my mind that transmission of speech can be effected in this way, the only doubt being as to whether the poles could be placed sufficiently far apart to make the arrangement of practical use.

AGB see page after pictures for continuation 20

Full Tetrahedral Construction

Number of Cells On Side In first layer In whole structure 1 1 1 2 3 4 3 6 10 4 10 20 5 15 35 6 21 56 7 28 84 8 36 120 9 45 165 10 55 220 11 66 286 12 78 364 13 91 455 14 105 560 15 120 680 16 136 816 17 153 969 18 171 1140 19 190 1330 20 210 1540 21 231 1771 22 253 2024 23 276 2300 24 300 2600 25 325 2925 26 351 3276 27 378 3654 28 406 4060 29 435 4495 30 465 4960 31 496 5456 32 528 5984

Proportional Numbers

Squares Cubes 1 1 1 2 4 8 3 9 27 4 16 64 5 25 125 6 36 216 7 49 343 8 64 512 9 81 729 10 100 1,000 11 121 1,331 12 144 1,728 13 169 2,197 14 196 2,744 15 225 3,375 16 256 4,096 17 289 4,913 18 324 5,832 19 361 6,859 20 400 8,000 21 441 9,261 22 484 10,648 23 529 12,167 24 576 13,824 25 625 15,625 26 676 17,576 27 729 19,683 28 784 21,952 29 841 24,389 30 900 27,000 31 961 29,791 32 1024 32,768

DICTATIONS REGARDING LABORATORY EXPERIMENTS

At Beinn Bhreagh, Baddeck, N. S. 1904.

1904, June 19 Sunday At B. B. Hall.

June 19, 1904: — Dictated by A.G.B. to M.G.B.

Arrived here Saturday night June 11, 1904. And it not seems that it would be wise to make some sort of plan s for the distribution of my time. For years past I have formed the habit of retiring at 4:00 A. M. and I have come to the conclusion that it would be best for us all around if I could substitute early morning work for night work.

I propose starting for bed about 11:00 which plan should result in being in bed before midnight, in which case it should be possible for me to be in my study by 7:00 A. M. I propose to try this plan to the end of this month, and if successful, to keep it up. If not successful I will have to go back to my old plan of night work as I have a great deal of work on hand for the U. S. Census Office that demands concentrated thought, and uninterrupted time.

I propose to devote the morning hours up to 11:00 A. M. to census work and spend the hour from 11:00 to 12:00 in the open air looking over the place, and being at Mr. Mitchell's office at 12:00 o'clock. From 12:00 to 1:00 I attend to correspondence, and have laboratory work from 1:00 to 4:00. We shall require one-half hour more to write up record of experiments, so that days work should close at 4:30 giving the rest of the afternoon and evening for recreation and reading.

Meals:— Have my breakfast put out for me at night so that I may have it when I awake in the morning. Take a light lunch down to the laboratory which I can take after 2 1:00 P. M. as there is always plenty of time for me to take my lunch while experiments are going on. Dinner at 6:30.

1904

LABORATORY WORK

June 19, 1904: — The experiments that have been carried on in the laboratory for some years past have resulted in the discovery of a successful plan of building large and strong structures out of light material by using small tetrahedral frames, as elements of the structure. Just as we can construct a building of almost any desired kind out of bricks of the same size and shape, so we can build framework s of almost any kind of small tetrahedral frames tied together at the corners. During last winter one thousand tetrahedral frames have been constructed in the laboratory, each frame having a side of 25 cm. and five hundred of these frames have been covered on two adjoining sides with red silk or nainsook, converting them into winged cells of tetrahedral form. We thus have on hand five hundred empty tetrahedral frames and five hundred winged cells. These constitute our bricks from which we can construct large structures of various kinds. We can take these structures to pieces and use the material over again ad libi d t um .

We have as our main object, the building of a giant kite of a shape suitable to be used as the body of a flying machine to be supported on floats on the water , and to rise in the air carrying a load of 200 kilogrammes when towed by a steamer.

3

The mode of building the structure has been settled — namely — tying tetrahedral cells together by their corners and distributing the strain through groups of cells by beading of heavier material surrounding the groups. If we compare our structure to a living organism the light tetrahedral frames correspond to the organic cells constituting flesh and blood — the heavier beadings correspond to the bones of the skeleton supporting the soft flesh, and distributing strain s throughout the whole organism.

Points that are not settled are:— 1, The arrangement of the supporting surfaces, and 2, the exact form and construction of the floats. The first point is more important than the second, and will be the immediate object of our experiments.

In regard to the second point we developed last year, forms of floats that were successful. While such floats are not in every way satisfactory, still they are sufficient for the needs of experiment, and I have had them duplicated in the laboratory during the past winter, so that we now have on hand a sufficient number of floats to enable us to carry on experiments on the water with flying structures too large to be readily handled on the land.

In regard to the first point named, the arrangement of surfaces, we developed last year a flying structure called the "Mabel II of Beinn Bhreagh". Numerous experiments have convinced me that this is an admirable arrangement of surfaces for the purpose intended, excepting in one point, — the lifting power of the oblique surface s is so much inferior 4 to surfaces horizontally arranged that a structure designed to lift a load of 200 kilogrammes would have to be enormously larger if utilizing oblique surfaces, than if all surfaces were horizontal.

A structure however, composed almost exclusively of winged cells, seems to be much superior in stability to one utilizing mainly horizontal surfaces, and there is no question in my mind that the Mabel type gives us all the stability in the air that can be desired in a practical flying machine. It possesses automatic stability, and the steadiness of flight in a gusty wind is really quite remarkable. Of course in a practical flying machine automatic stability is of the first consequence and no amount of lifting power could compensate for lack of balance in the air.

Horizontal surfaces are markedly unstable, but by avoiding them altogether and using a multitude of small oblique surfaces well separated from one another so that the wind can blow through the whole structure and a squall strike it — substantially on both sides at the same time, we get a flying structure that is steady in gusty air — a desideratum indeed. Last year we tried to combine oblique and horizontal surfaces in the hope that the horizontal surface would give us the desired lift, and oblique surfaces the stability, and we developed the Victor type of kite.

There is no question in my mind that this form is superior in lifting power to Hargrave's box kites when arranged substantially like the cells of the box kite, — that is, with one set of covered cells in front and another set 5 in the rear, well separated by empty framework. But the empty framework constitutes a dead load to be carried, whereas in the Mabel form we have no similar dead load, and it is questionable whether a Mabel kite of inferior lifting power without any dead load to be carried may not be equal in resultant lifting power to the Victor kite with its necessary empty framework, while at the same time superior in its ability to withstand a gusty wind.

Just before leaving Beinn Bhreagh last winter however, the discovery was made that the two sets of cells on the Victor kite if placed end to end like a pair of birds wings, would fly by themselves, thus dispensing entirely with the empty framework that had hitherto been considered necessary. This alters the problem entirely. The Victor cells thus united — when flying in the air — resemble forcibly a soaring bird and the kite flies almost over head. I was so convinced last year that in this form of kite we had a new departure of the greatest importance and value, that I gave it a distinct name, “The OIONOS” — the Greek “Bird of Augury” the Bird of Omen — and I feel that we cannot consider the arrangement of supporting surfaces as settled without further experiment to develope the possibilities of the Oionos form as compared with the Mabel. THIS is the immediate work of the laboratory.

A. G. B. per M. G. B.

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1904, July 3, Sunday At B. B. H.

July 3, 1904 Dictated by A.G.B. to M.G.B.

In considering the character of a flying structure to be entrusted with a human life, stability in the air under varying conditions is of the first consequence.

Important as it is to make an arrangement of surfaces having great lifting power it is still more important that the conditions of stable equilibrium in the air should be thoroughly investigated and understood; for what would it profit a man to gain the whole lifting power of the atmosphere and lose his own equilibrium in the air, — and what would the world profit from fatal experiments. They retard progress by discouraging others.

The stability of the Hargrave box kite and the still more remarkable stability of the tetrahedral kite of regular construction — in both of which forms the center of gravity lies in an empty space — and the instability of kites generally which have supporting surfaces under the center of gravity or at the center, forces the conclusion that an important principle of stability lies in the omission of resisting surfaces in the immediate neighborhood of the center of gravity. In the regular tetrahedral construction, an octahedral space exists within each set of four cells and the center of gravity of the four cells lies in this empty space. As we increase the number of cells we obtain not only this empty space in each set of four cells, but an additional octahedral space of still larger size between each four sets, within which lies the center of gravity of the four sets. Thus with every increase in the number of cells the empty space around the center 7 of gravity becomes larger and it is a matter of simple observation that the many celled tetrahedral kite is much more stable in the air than kites of similar construction having a smaller number of cells: So the general conclusion seems to be arising that stability is favored by the omission of resisting surfaces from the center of the kite and their removal to as great a distance as practicable from that center.

If we treat the matter ideally let us picture the kite structure as a sphere with the center of gravity in the middle. Then stability is favored by limiting the resisting surfaces as much as practicable to the outer surface of the sphere, the resisting surfaces thus forming a sort of spherical shell, and the larger the diameter of the sphere the greater the stability. This idea is not exactly correct — for, that portion of the spherical shell which is below comes directly under the center of gravity introducing an element of instability when downward motions are considered. The portion at the top also is inadvisable because far removed from the center of gravity, which would tend to make it oscillate like a pendulum. Considering the top and bottom portions of the sphere as the North and South poles, it is the equatorial section of the resisting shell that contributes most to stability under downward motion. The most stable section thus constitutes a horizontal ring having the center of gravity in its plane.

Now consider our spherical shell under the influence of a gust of wind striking it sideways at some point of the equator, then the portion of the shell directed towards the wind introduces an element of instability, especially that 8 point on the equator opposite the center of gravity and between it and the wind. The most stable part of the shell would be a vertical ring passing through the poles.

Thus to produce stability during downward motions under gravity we want a horizontal slice of the sphere through the equator cut out in the middle so as to constitute a flat ring. To produce stability under side gusts we want a vertical slice of the sphere passing through the poles with the central portion cut out, constituting a vertical flat ring presented edgeways to the front — the resisting surfaces facing the gusts. This gives us two flat rings with their planes at right angles. There is one defect however about this; it is impracticable to construct a plane or a ring that does not offer resistance edgeways, and the vertical flat ring that contributes stability under the action of side gusts introduces an element of instability during descent under gravitation, because a portion of it comes directly under the center of gravity. And the horizontal flat ring — in a similar manner introduces an element of instability under side gusts of wind because a portion of it comes directly between the wind and the center of gravity.

By doubling each ring we can get over this difficulty; for example instead of having one equatorial horizontal ring, have two parallel rings — one North and one South of the equator then in case of side gusts of wind the center of gravity will not be shielded and the edge resistances North and South will be an element of stability against side gusts, especially if they are well separated from one another. In a similar manner 9 two vertical rings well separated will be an element of stability under descent.

This goes right back to an old conception of mine — the spherical cell — a model of which I constructed of paste — board last year or the year before — but which has not yet been tested in actual practice.

AGB

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1904, July 8, Friday At B.B.

Dictated by A.G.B. to M.G.B.

July 8, 1904:— Some important experiments have been made within the last few days at the Laboratory to test how far horizontal surfaces could safely be added in kites of pure tetrahedral construction without materially affecting their stability, — four 16 celled tetrahedral kites out of 25 cm. winged cells.

In one of these kites the frame spaces for four horizontal aeroplanes were covered with white nainsook, making four horizontal surfaces each 25 cm. square, and one in the centre of each group of cells. This added 2500 sq. cm. to the lifting surface of the kite without additional framework.

In another kite these four spaces were left uncovered, but the large central space was filled in with a horizontal surface 50 cm. sq. The added surface in this case also amounted to 2500 sq. cm.

A third kite combined the horizontal surfaces of the others; having a central surface 50 cm. sq. and four 25 cm. sq., thus adding 5000 sq. cm. to the lifting surface of the kite without additional framework.

The fourth kite had no horizontal surfaces at all and was simply a standard tetrahedral kite of pure construction having a large octahedral space in the middle.

These kites were flown comparatively at the same time and with the same length of cord (200 m). The wind even at that elevation was extremely feeble and fluctuating, so much so that the kites would occasionally appear to be in a calm, falling together for several metres and then recovering 11 themselves with the next gust. The kites with the added horizontal aeroplanes were undoubtedly superior to the standard kite in a supporting wind. The one with 5000 sq. cm. was the best and flew well in a wind which would hardly support a standard.

The kites with horizontal surfaces however, while very satisfactory kites in their general behavior, seemed to be less still than the standard — moving slowly from right to left to a much greater extent than the standard, and there can be no doubt that the horizontal surfaces introduced are an element of instability that is absent when oblique surfaces alone are used. This instability was much marked when the wind fell and the kites began to fall. The kites with the horizontal surfaces — all of them — turned completely over in the air, but recovered themselves. The standard fell gently and slowly without making a somersault. The difference in this respect was most marked. In a fully supporting breeze there was not much difference. All of the kites flew well — but those with horizontal surfaces flew at a higher angle than the standard — the one with the greatest amount of horizontal surfaces was the best.

I would like to dictate some account of other important experiments with a 20 celled kite, a 64 celled kite, and a short tailed Oionos kite of red silk, but it is late and I must postpone further remarks. Before closing however, I would like to put down one thought of importance.

Tetrahedral kites while generally characterized by great steadiness in the air, sometimes act in a most extraordinary and mysterious way.

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We have had such kites tumbling over and over in the air, whirling around the string as a center, but in all these cases inspection has revealed a defect of construction — now it has been a broken stick, and again a crooked keel, so that the stern cell has acted as a rudder and steered the thing continuously to one side. But this is not what I mean — there is an abnormal action of the kite not associated with any obvious defect which makes its appearance occasionally in a strong wind. A kite which has flown beautifully and steadily in a moderate breeze, sometimes turns over on its side when the wind freshens, and gradually and slowly goes down to the ground. If we reel in the line, thus increasing the pressure on the line, or if the wind freshens, it goes down more rapidly, whereas if a lull occurs, or if we slack the line, the kite rights itself and begins rising. We have examined many kites without discovering any defect and the cause of the abnormal action has been quite a mystery. All we could surmise from the temporary nature of the defect was that a temporary distortion of the kite was produced under the pressure of gusts of wind — though why it should be so we could not imagine. It has recently occurred to me that perhaps the defect may be due to the fact that in each winged cell, though the silk is sown on to the side sticks, it has not been sowed to the keel sticks of the ceel. I fancy that a sudden gust of wind may cause a bagginess of the silk in one wing, at the expense of the other — that is, one wing may become baggy and still the another be stretched tight on account of the absence of fastening to the keel stick. If this is so, all the cells of a kite would become concave on one side and tight on the other, producing a one-sided 13 distribution of the surface that might account for the peculiar behavior noticed above. We now sew the silk to the keel sticks of cells in every case.

A. G. B. per M. G. B. 31